Denoising EEG Signal Using Wavelet Transform

R. PRINCY, P. THAMARAI, B.KARTHIK

***Abstract*—Electroencephalogram (EEG) signal is the recording of spontaneous electrical activity of the brain over a small interval of time. Signals are produced by bombardment of neurons within the brains which are measured and evaluated by EEG. EEG signals are low voltage signals that are contaminated by various types of noises that are also called as artifacts. As these signals are used to diagnose various types of brain related diseases like narcolepsy, Sleep apneasyndrome, Insomnia and parasomnia it becomes necessary to make these signals free from noise for proper analysis and detection of the diseases. Various noise removal techniques such as Independent Component Analysis [ICA], Principle Component Analysis [PCA] ,Wavelet Transform and Wavelet Packet Transform are available and can be implemented in mat lab.. All the above methods can be used for EEG signal denoising through noise to the original signal and then implement the noise reduction technique and their performance can be evaluated based on the factors such as SNR and MSE. In this paper, a statistical method for removing artifacts from EEG recordings through wavelet transform without considering SNR calculation is proposed.**

***Index Terms*—EEG, ICA, PCA, SNR, MSE.**

I. Introduction

Electroencephalography (EEG) signal is the recording of spontaneous electrical activity of the brain over a small period of time. The language of communication with the nervous system is electric. The neurons of the human brain process information, by changing the flow of electrical currents across their membranes. These changing currents generate electric and magnetic fields that can be recorded from the surface of the scalp by placing electrodes on the scalp. The potentials between different electrodes are then amplified and recorded as the Electroencephalogram (EEG); which means the writing out of the electrical activity of the brain (that which is inside the head). EEG recordings therefore, complete knowledge about overall activity of the millions of neurons in the brain. Brain is one of the most important organs of humans, for controlling the coordination of human muscles and nerves. The EEG is the recording of brain's electrical activity. EEG is one commonly used non-invasive facility to investigate the intricacy of human brain. The EEG is used in the evaluation of brain disorders. It is also used to evaluate people who are having problems associated with brain. An EEG is also used to determine brain death.

The analysis of continuous EEG signals is complex. Different types of EEG waves are categorized by the frequency namely Alpha waves (7.5-14 Hz), Beta waves (14-40 Hz), Gamma waves (above 40 Hz), Theta waves (4-7.5 Hz), Delta waves (0.5-4 Hz)[2].All the waves represents different mental states of the patient.

EEG signals are having very small amplitudes and because of that they can be easily contaminated by noise .The noise can be electrode noise or can be generated from the body itself. The noises in the EEG signals are called the artifacts and these artifacts are needed to be removed from the original signal for the proper analysis of the EEG signals .The various types of noises that can occur in the signals during recordings are the electrode noise, baseline movement, EMG disturbance and so on .We need to remove these noises from the original EEG signal for proper processing and analysis of the diseases related to brain.

Various denoising techniques have been implemented for removal of the artifacts from the EEG signals. Some of the techniques that can be used for the noise removal are ICA denoising, PCA method of denoising, Wavelet based denoising, and Wavelet packet based denoising and so on. All the above methods can be implemented for the denoising of the EEG signals and their performance evaluation can be done by measuring the parameters like SNR, PSNR, and MSE etcEEG recording method could be categorized into two groups: invasive electrode and non invasive electrode.

A deficiency of the invasive EEG acquisition method is it usually took more than one month for the patient to recover completely from the surgery. The advantage of this invasive method is its high accuracy and sensitivity. The signal to noise ratio of invasive EEG is from 10 to 100 times higher than non-invasive EEG recording method. Currently, invasive EEG signal recording method emphasis in brain disease diagnoses. The noise reduction technique using independent component analysis (ICA) and subspace filtering is presented. [1]They applied subspace filtering not to the observed raw data but to a de-mixed version of these data obtained by ICA. Finite impulse response filters are employed whose vectors are parameters estimated based on signal subspace extraction. ICA allows to filter independent components. After the noise is removed they reconstruct the enhanced independent components to obtain clean original signal. The various denoising methods were studied for EEG denoising[2]. The signals were denoised using PCA, ICA, and Wavelet method. Wavelet transform analyses the signals in both time and frequency domain and also signals with low noise amplitudes

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can be removed from the signals by selecting the best wavelet to decompose the signal..Wavelet Packet transform was used for EMAT noise suppression which decomposes the signal in both low pass and high pass component and shown SNR improvement of 19 dB.The wavelet based threshold method and Principal Component Analysis (PCA) based adaptive threshold method to remove the ocular artifacts[3]. The disadvantage of PCA is the requirement that artifacts are uncorrelated with the EEG signal. This is a stronger requirement than the independency requirement of ICA.

II. Existing System And Proposed System

The existing methods available for removal of artifacts from EEG are:

1. Linear combination and Regression
2. Principle Component Analysis
3. Blind Source Separation
4. Non Linear Adaptive Filtering
5. Source Dipole Analysis
6. Linear Filtering

A. linear combination & regression (LCR):

i) Features:

This is a common Technique for removal of ocular artifacts from EEG signal. It uses the Least Mean Square method. The main problem with linear combination and regression approach is that the EOG signal is to be subtracted from the EEG signal. This subtraction of the EOG signal may also remove part of EEG.

ii) Dis-advantages:

One problem with using the above linear combination and regression approach is that the EOG signal to be subtracted from the EEG signal. However, subtracting the EOG signal may also remove part of the EEG signal. EMG artifacts do not have any reference channels, and applying regression using signals from multiple muscle groups requires multiple reference channels.

iii) Uses:

Regression techniques for the removal of head-movement artifacts, for jaw clenching, spit swallowing can be applied.

B. Principle Component Analysis (PCA):

Multi-channel EEG recordings can be expressed by a P(time points) x N(channels) matrix, E, and decomposed as a product of three matrixes ,E=USVT, where U is an P x N matrix such that UT U =I, S is an NxN diagonal matrix, and V is an NxN matrix such that VTV=VVT=1.If E is an EEG epoch of N channels and P time points, U contains its N normalized Principal Components that are decor related linearly and can be remixed to reconstruct the original EEG. PCA uses the eigenvectors of the covariance matrix of the signal to transform the data to a new coordinate system and to find the projection of the input data with greater variances. The components of the signal are then extracted by projecting the signal onto the eigenvectors. PCA has been shown to be an effective method for removing ocular artifacts from EEG signals.

Dis-advantages:

One disadvantage of PCA is the requirement that artifacts are uncorrelated with the EEG signal. This is a stronger requirement than the independency requirement of ICA.

It has been observed that PCA cannot completely separate eye-movement artifacts, EMG and ECG artifacts from the EEG signal, especially when they have comparable amplitudes.

PCA also does not necessarily decompose similar EEG features into the same components when applied to different epochs.

C. Blind Source Seperation (BSS):

BSS techniques separate the EEG signals into components that “build” the EEG signals. They identify the components that are attributed to artifacts and reconstruct the EEG signal without these components. Among the BSS methods, Independent Component Analysis (ICA) is more widely used.

BSS techniques have the ability to separate EEG signals to spatial components; specialists are then are called then to identify the artifactual components remove them and reconstruct the signal.

Dis- advantages:

The main disadvantage is that specialist should be available to recognize and reject the artifactual components.

This is a time consuming procedure which can lead to cerebral activity distortion if will not be performed with great care.

D. Linear filtering:

Linear filtering is useful for removing artifacts located in certain frequency bands that do not overlap with those of the neurological phenomena of interest. For example, low-pass filtering can be used to remove EMG artifacts and high-pass filtering can be used to remove EOG artifacts.

Advantages:

The advantage of using filtering is its simplicity. Also the information from the EOG signal is not needed to remove the artifacts.

Dis-advantages:

This method, however, fails when the neurological phenomenon of interest and the EMG, ECG or EOG artifacts overlap or lie in the same frequency band.

As a result, a simple filtering approach cannot remove EMG or EOG artifacts without removing a portion of the neurological phenomenon.

More specifically, since EOG artifacts generally consist of low-frequency components, using a high-pass filter will remove most of the artifacts and for EMG artifacts, using a low pass filter will remove some artifacts.

Uses:

Linear filtering was commonly used in early clinical studies to remove artifacts in EEG signals.

III. Independent Component Analysis (ICA)

Independent component analysis (ICA) was originally proposed, to recover independent source signals, s={s1(t)……sN(t),(e.g voice, music or noise sources) after they have been mixed by an unknown matrix. Nothing is to be known about the sources or mixing process except that there are N different recorded mixtures, x={x1(t)….., xN(t)}.The task is to recover a version u=Wx of original sources s, identical for scaling and permutation, by finding a square matrix, W, specifying spatial filters that invert the mixing process linearly.

This algorithm is highly effective at performing source separation in domains where In case of EEG signals, the multi-channel EEG recordings are mixtures of underlying

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brain and artifact signals. Volume conduction is thought to be linear and instantaneous and hence (a) is satisfied (b) is also reasonable because sources of eye and muscle activity, line noise and cardiac signals are not generally time locked to the sources of EEG activity. Assumption c) Here the effective number of statistically independent signals contributing to scalp EEG is not known but numerical simulations have confirmed that the ICA algorithm can accurately identify the time courses of activation and scalp topographies of relatively large and temporally independent sources from scalp recordings even in the presence of low-level and temporally independent source activities.

IV. WAVELET TRANSFORM (WT)

Wavelet transforms are signal-processing algorithms similar to Fourier transforms that are used to convert complex signals from time to frequency domains. However, unlike Fourier transforms, wavelets are able to functionally localize a signal in both time and frequency space, thus allowing transformed data to be simultaneously analyzed in both domains (frequency and time).

The wavelet transform of the noisy signal generates the wavelet coefficients which denote the correlation coefficients between the noisy EEG and the wavelet function. Depending on the choice of mother wavelet function (which may resemble the noise component),larger coefficients will be generated corresponding to the noise affected zones. Ironically smaller coefficients will be generated in the areas corresponding to the actual EEG. The larger coefficients will now be an estimate of noise.

Appropriate threshold limit is to be found which separates the noise coefficients and the signal coefficients.

A proper thresholding function is to be chosen to discard the noise coefficients appropriately. Thresholding functions decide upon which coefficients should be retained and what should be done to them.

Hence discarded coefficients would result in the removal of noise, and the retained coefficients represent the wavelet coefficients of the de-noised EEG signal.

On taking the inverse wavelet transform, the de-noised signal is obtained. Hence the selection of threshold and thresholding function plays a crucial role in EEG denoising.

Proposed system

In our project the new method to identifying the spikes which may contain artifactor not is proposed. Algorithm is

1. Covariance of x (n), x (n+1) for each level is taken..
2. Continuous two positive values should be considered as spike.
3. Difference between highest and lowest value in the peak is taken.
4. Set up an EEG amplitude range as threshold value.
5. Spike is detected.

V. BLOCK DIAGRAM

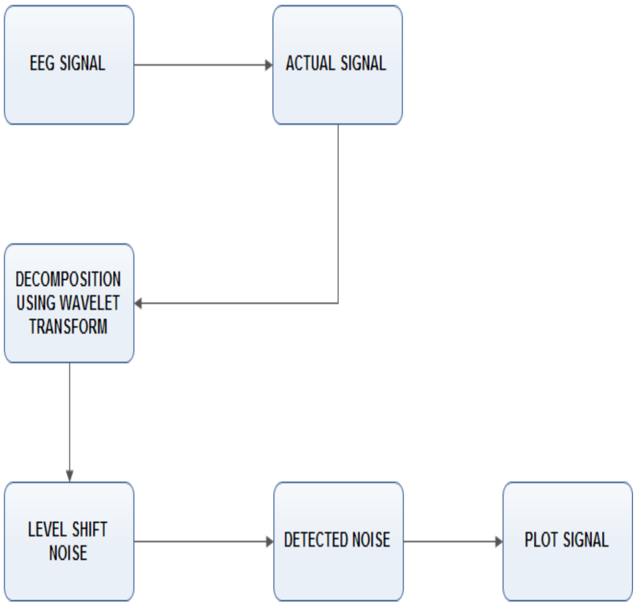

Fig 1 Block diagram of proposed system

Steps involved:

1. Get the EEG signals in the database
2. Extract the actual signal by demodulates the signal to remove the carrier.
3. Decompress the signal to perform level shifting.
4. Split the level of the EEG signal based on the factor PRST.
5. Identify the peak and minimum value in each level.
6. Set up the EEG amplitude as threshold value.
7. Identify the noise.
8. Perform denoising using wavelet transform.
9. Plot the signal

EEG Theory:

EEG is normally used to record the brain wave in medical treatment. The recording is usually taken by electrodes (small metallic discs) pasted by an electricity conducting gel to the surface of the scalp.

In **EEG** recording, a powerful electronic amplifier increases several hundreds or thousands of times the amplitude of the weak signal (less than a few micro volts) which is generated in this place. In the past, a device called galvanometer, which has a pen attached to its pointer, writes on the paper strip, which moves continuously at a fixed speed past it. In the present time, with the advent of powerful electronic computer and very high storage, we can use A/D device to transform signal between electrode and computer. A lot of data can be recorded and easily analyzed and printed. One pair of electrodes usually makes up a channel. Since earlier times, it is known that the characteristics of **EEG** activity change in many different situations, particularly with the level of vigilance: alertness, rest, sleep and dreaming. The frequency of wave change can be labelled with names such as alpha, beta, theta and delta. Particular mental tasks also alter the pattern of the waves in different parts of the brain. A small picture to show how eye blink contaminates EEG signal

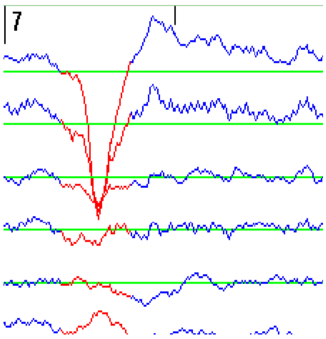

Fig 2: contamination of EEG signal due to blinking of eyes

Data Collection:

Data is collected on a routine basis at the Psychology Department, UW Madison for various research studies. I was involved in setting up of an experiment where data is collected from human subjects. I sat through some data collection sessions. In addition, a large volume of data was collected and manually scored.Just to give an insight,here is how a typical cap electrode looks like.

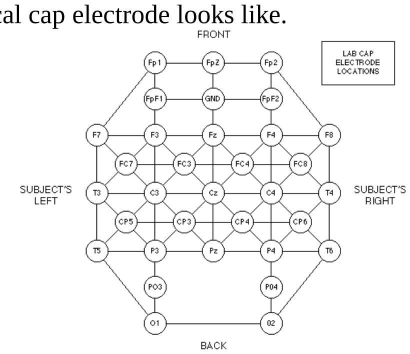

Fig 3: EEG data collection

This unit has an active amplifier, inverter amplifier and signal mixer in the input to full wave rectify without diode offset error.

The integrator section is a balanced bleed-fill network to maintain equal charge and discharge time constants.

The o/p is the true average of the input signal.

The time constant is adjustable from 50ms to 2 secs making the unit suitable for integration of bio potentials up to the lowest band of EEG signals.

The raw and integrated signals look like these.

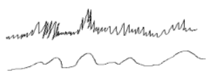

Fig 4: Representation of raw and integrated signal

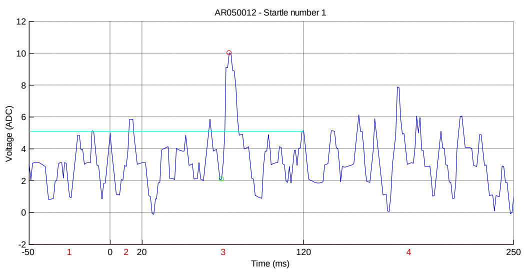

Figure 5: Representation of EEG signal with error.

Data is streamed into stimulus files.I used a program startle.m written by Adrian Pederson to read in the data from stimulus file and convert into understandable parameters.

VI. Result and Discussion

Artifacts in EEG signal play an important role. It is caused by various factors like line interference, EOG, ECG. The removal of ocular artifact from scalp EEGs is very important in brain activity. These noises increase the difficulty in analyzing the EEG and obtaining clinical information. For this reason, it is necessary to design a procedure to decrease such artifacts in EEG signal. We are going to remove artifacts from EEG signal through wavelet transforms by detecting its spikes without considering SNR.

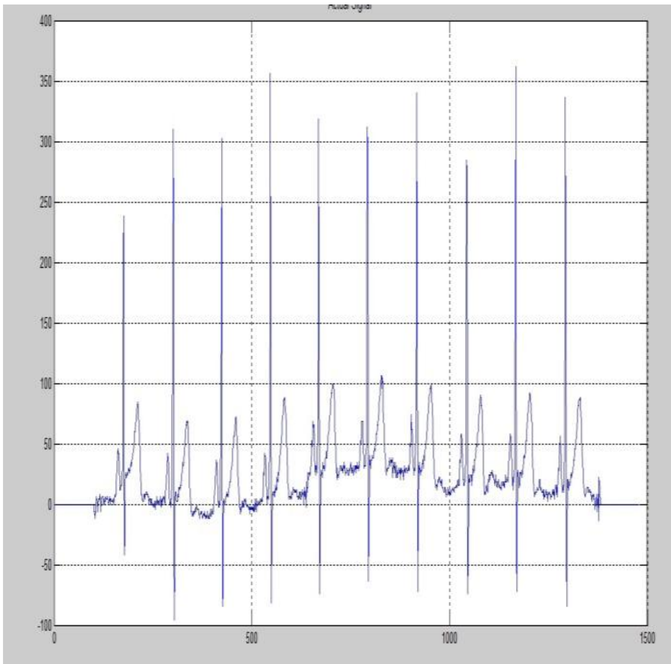

Fig 6: Normal EEG signal

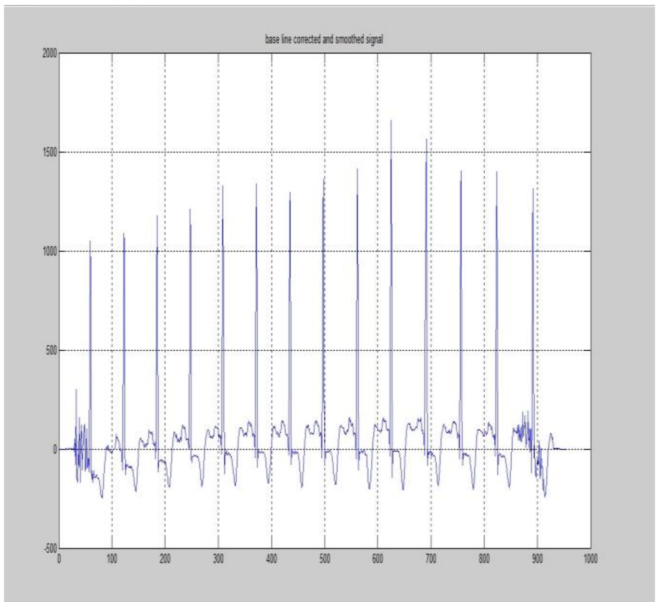

Fig 7 Baseline corrected and smoothed signal

VII. Conclusion

The EEG signals were denoised using Wavelet transform method. The analysis of signals at various stages including denoised signal were plotted .Wavelet transform analyses the signals in both time and frequency domain and also signals with low noise amplitudes can be removed from the signals by

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selecting the best wavelet to decompose the signal. In wavelet transform we decompose only the low pass components of the signals. Wavelet Packet transform was used for EMAT noise suppression which decomposes the signal in both low pass and high pass component and shown SNR improvement of 19 dB. .Till now only simple wavelet transform is implemented for EEG denoising in future its advancement wavelet packets can be used for denoising EEG signals which will give better results.

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